Method for treating powdery particles

The present invention relates to a method for a preliminary treatment of particles of a powder in a dry surface treatment process before
5   applying the powder particles on a surface of a substrate by utilizing an electric field created by electrodes, which are located at opposite sides of the substrate in such a way that at least one first electrode is located at the side of the substrate to be coated, and at least one second electrode is located at the opposite side of the substrate.

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The dry surface treatment process of different substrates, such as paper, board, plastic, or metallic substrates, comprises dry powder application followed by a finishing step, for example thermomechanical fixing. The application of the powder utilises an electric field to transfer
15   the powder particles to the surface of the substrate and to enable an electrostatic adhesion prior to the finishing. Both the final adhesion and the surface smoothening of the dry powder are executed simultaneously through thermomechanical treatment or another suitable treatment. The powder, which is used, may be a coating
20   composition comprising inorganic particles and binder particles, or a film forming material, which can be finished so that a pinhole-free film layer is formed.

In a dry surface treatment process, the charging of the powder has an
25   essential role. If some inadequacies relating an amount of the charged particles, or a level of charging of a particle occur, it has an effect on efficiency and a cleanliness of the process. If the particles of the dry powder do not adhere properly to a substrate it causes an uneven powder layer on the substrate, dusting, material losses, and possibly
30   harmful deposits.

The method of the invention is an enhancement to the dry surface treatment process, and it diminishes the above-mentioned problems of the dry surface treatment process. The method is characterized in that
35   the particles of the powder are pre-charged before bringing them into the electric field.

2

The method of the invention makes the efficiency of the dry surface treatment process better because the dry powder places itself on the substrate properly, and no material losses occur. As a consequence, also a coating layer of a higher quality is achieved. A clean process
5   without dusting is also attained.

In a dry surface treatment process, an electric field is created between electrodes, which are in different potentials. A substrate to be coated is between the electrodes. At least one of the electrodes may be a corona
10   charging electrode which charges surrounding gas. The charged gas atoms, molecules or molecule groups attach to particles of the coating powder, thus giving a charge to the particle.

A force according to the equation $\bar{F} = q\bar{E}$, where $\bar{E}$ is an electric field,
15   F is the force, and q is a charge, has an influence on a charge q in an electric field E. The force tends to convey the charge in the electric field, and in a stationary electric field only a position of the charge is meaningful. When a potential of the electric field is known, the strength of the electric field in a certain position is derived from the following
20   equation:

$$\bar{E} = -\frac{\partial V}{\partial n}\bar{u}_n,$$

Note inconsistancy in use of bar

where
25    $\bar{E}$ is the strength of the electric field,
      V   is the potential of the electric field, and
      $\bar{u}_n$ is the unit vector of the perpendicular of the plane.

The strength of the electric field can also be evaluated by the electric
30   charge density when the relation between the electric flux density and the strength of the electric field is taken into consideration. The equation below is Gauss's law.

$$\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z} = \frac{\rho}{\varepsilon},$$

3

where

$E_{x,y,z}$ are the dimensional strengths of the electric field,

5   ρ is a local electric charge density, and

        ε is the dielectric constant of the examined space.

As seen from the equation above, in a stationary electric field the charges create the field, and the distribution and the magnitude of the

10   charges determine the strength of the field in different positions.

If a conductive particle (radius a, charge q) is exposed to an uniform electric field E_0 in a unipolaric ion concentration N_0, the electric field at the particle is formed from two components, namely an electric field

15   created by the particle itself due to its own charge, and an outer electric field which is changed by the charge of the particle. This field is described by an equation

$$E = 3E_0 cos\theta - \frac{q}{4\pi\varepsilon_0 a^2}$$

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        where

        E is the resultant electric field,

        θ is the insidence angle of the electric field focused to a

25   particle,

        ε_0 is the dielectric constant of the free space,

        a is the diameter of the particle, and

        q is the charge of the particle.

30   The term $3E_0cos\theta$ describes the change of the electric field as a consequence of the presence of the conductive particle. E_0 is the undisturbed field. The charging of the particles is great, and it is restricted only by the ions conveyed onto the particle by the electric field. The change of the charge is defined as a stream, and it can be

35   described by the equation

4

$$\frac{dq}{dt} = N_0 eb \int_{\theta}^{\theta_0} \left(3E_0 cos\theta - \frac{q}{4\pi \, \varepsilon_0 a^2} \right) dA \qquad\qquad (4)$$

where

5 q is the charge of the particle,
   b is the mobility of ion,
   e is the charge of the electron,
   θ_0 is the critical angle of to the particle streaming charge,
   dA is the area of the component $= 2 \, \pi a^2 sin\theta d\theta$, and
10 t is time

The above mentioned equation shows that the charge continues to stream to the particle until the field created by the particle and the outer field are balanced out. When a saturation charge is known, the
15 level of charging can be derived from the equation

$$q(t) = q_s \frac{1}{1+\tau/t}$$

where $\tau = 4\varepsilon_0/N_0 eb$
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For conductive materials, the saturation charge is $q_s = 12\pi a^2 \varepsilon_0 E_0$. For non-conductive materials, to the equation shall be added $3\kappa/(\kappa+2)$.

The diffusion charge has also an effect on the particle. As a function of
25 time, the diffusion charge can be expressed by the equation

$$q(t) = \frac{akT}{e} ln\left(1 + \frac{\pi avN_0 e^2 t}{kT} \right)$$

where
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   k is Bolzman's constant,
   T is the temperature (K),
   e is the charge of the electron,
   v is the thermal velocity of ions (rms),

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N_0	is the average amount of molecules in a certain volume, and
t	is time.

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As can be concluded from the above mentioned equations, time is an important factor in charging of particles.

The pre-charging of the particles of the coating powder can be made either when the particles are brought at the final electric field or before bringing them into the final electric field. The aim of the pre-charging is to obtain a longer charging period compared to the process having only one charging step. The benefits of the longer charging period are a more homogenous charging level and a greater force of the electric field having influence on the particle.

The first embodiment of the invention is to pre-charge the particles of the coating powder when they are about to arrive into the final electric field. The pre-charging process is conducted in such a way that at least one charging electrode comprising a feeding nozzle is located farther away from the substrate to be coated. The dry powder is led to the charging electrode, and particles of the dry powder are charged by the charging electrode. After that the pre-charged particles enter to the final electric field formed by the other charging electrodes, for example corona charging electrodes, and a grounding electrode, or an electrode having an opposite sign. The pre-charged particles are blown towards a substrate to be coated. The substrate is preferably in a web form. The grounding electrode can be a stationary platy electrode, or it can be a roll rotating about its axis. The rotating roll is a preferred choice.

The second embodiment of the invention is to pre-charge the particles of the coating powder in another electric field(s) before the final electric field. In this embodiment, a dry powder is led first to a separate electric field and after that to the final electric field. Particles of the dry powder are pre-charged in a charging unit comprising a corona charging electrode, an electrode having a different potential compared to the

6

corona charging electrode (e.g. a grounding electrode, an electrode in a lower or opposite potential), and a feeding nozzle.

Particles may also be charged by triboelectric charging, for example
5 charging the particles by a friction between the particles, and walls of a transfer pipe, or a storage bin. After that the particles enter to another charging unit, which conducts the final charging of the particles. The final electric field is formed by electrodes at opposite sides of the substrate. The electrodes can be corona charging electrodes and a
10 grounding electrode, other suitable electrodes and a grounding electrode, or electrodes being in different potentials at opposite sides of the substrate. The pre-charged particles are blown towards a substrate to be coated through a nozzle.

15 In the following, the invention will be described by means of figures. In figures,

Fig. 1.   · shows the first embodiment of the invention, and

20 Fig. 2.   shows the second embodiment of the invention.

According to Fig.1, a dry powder is led to a charging electrode 1 comprising a feeding nozzle. Particles of the dry powder are charged by the charging electrode 1. The charging electrode is located farther
25 from other electrodes 2 so that the particles are pre-charged when they enter to the final electric field formed by the corona charging electrodes 1, 2 and a grounding electrode 3. The pre-charged particles are blown towards a substrate 4 to be coated. The substrate 4 is preferably in a web form. The grounding electrode 3 can be a stationary platy
30 electrode, or it can be a roll rotating about its axis. The rotating roll is a preferred choice.

According to Fig. 2, a dry powder is led to a first electric field and after that to a second electric field. Particles of the dry powder are charged
35 in a charging unit 7 comprising a corona charging electrode 6, a grounding electrode 5, and a feeding nozzle 8. The particles are pre-charged in the first electric field created in the charging unit 7 before

7

entering to the second electric field formed by the corona charging electrodes 2 and a grounding electrode 3. The pre-charged particles are blown towards a substrate 4 to be coated. As in the embodiment shown in Fig. 1, the remarks concerning the form of the substrate 4

5   and the preferred grounding electrode 3 are also valid in this embodiment.

The invention is not restricted to the description above, but the invention may vary within the scope of the claims.

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